Coast Guard Evacuation Analysis Plan

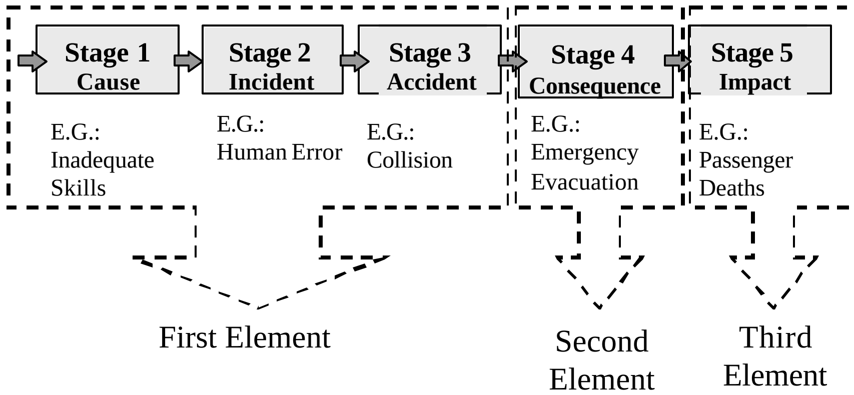
1. Background

The recent adoption of the Interim Guidelines on RoRo passenger vessel evacuation analysis provides a strong start toward meeting the IMO Secretary General's charge to ensure that, with today's rapidly increasing passenger vessel capacity, adequate provisions are provided for passenger safety. The Correspondence Group established for FP44, 45 and 46 continues this strong start, with several Administrations working on refining the "simplified" evacuation methodology, and expanding its scope to include High Speed Craft and other passenger vessels.

Concerns have been raised regarding the "simplified" evacuation analysis methodology, particularly whether the assumptions used are reasonable. As the current methodology is almost wholly based on that which is used for buildings, the United States shares these questions. Most notable of the areas of uncertainty in the existing methodology is the assumption that the effects of the ship's motions, passengers' age and disability, restricted visibility due to smoke and other neglected items are all accounted for in the safety factor of 2. The safety factor may be either increased or decreased based on ongoing research into the effects of these factors on the time of evacuation. The other notable assumptions include that people can move unhindered, no escape routes are blocked, and all passengers and crew evacuate via the primary route. In order to assist the correspondence group in this endeavor and develop our own evacuation methodology for domestic regulations, the USCG is currently developing a passenger vessel risk assessment methodology, including a detailed analysis of the evacuation process. Simultaneously, several other administrations are also seeking to validate whether the following assumptions can be used without loss of accuracy.

The following is a detailed breakdown of the USCG approach to developing a more detailed and versatile passenger vessel evacuation methodology. The approach is comprised of the three elements as outlined in Figure 1. This is based around the causal chain representation of the progression of events from basic causes of incidents and accidents, up through their consequences (e.g., passengers at risk) and eventual impacts (e.g., deaths and injuries). The first element from Figure 1 addresses the portion of the causal chain leading up to and including the various accident types (collisions in the example provided) that could lead to the need to evacuate a passenger vessel. For the second element, the work involved will focus on developing and populating a model to characterize the decision to evacuate a vessel as well as the actual evacuation process. The third element of this research is to investigate the impact of the abandon ship scenario, including the effect of passengers exposed in lifesaving equipment (e.g., life rafts, life boats) and the assessment of search and rescue (SAR) capabilities. The goal for this methodology is to provide a more detailed and descriptive approach to evacuation analysis that will allow consideration of various approaches for ensuring passenger safety, particularly given the rapid growth in vessel size and capacity. The United States has begun the following approach and is looking for additional collaboration from the international community in any of the areas shown below.

Figure 1: Causal Chain



1.1. The Planned Treatment of the First Element

The first element, as noted, addresses the portion of the causal chain leading up to and including the various accident types. The outcome of this phase will be a characterization of the likelihood of a vessel being in a state that requires evacuation, as well as the conditions for the evacuation process (e.g., accident type, vessel type, number of passengers, etc.).

1.1.1. Develop Model for Determination of Probability of Accident

Much of the prior research on risk assessment in the maritime industry can be used to facilitate development of a model for the probability of various accidents. For this analysis, modifications of traditional models will be made to allow for the evaluation of vessel state, vessel type, geographic region and number of passengers. The use of these and other variables will allow for detailed models for the characterization of the passenger evacuation process.

1.1.2. Evaluate Data Sources for Probability of Accident

At present, the primary data source being used in our work for this portion of the analysis are U.S. Coast Guard accident statistics. While this data set will likely be sufficient for many types of passenger vessels, it does not account for High Speed Craft, for which U.S. experience is limited. For this data collection effort, a collaborative approach among the international community would be strongly suggested. For example, one potential source is the recently completed Formal Safety Assessment of High Speed Craft by the UK. The premise behind using this data set is that while the individual administration's databases lack the robustness for analysis, collectively, their experience provides an adequate basis.

1.1.3. Determine Probability of Accident

Using the model and data developed previously, the probability of an accident requiring passenger evacuation will be determined. As noted previously, this will include an evaluation of this probability by accident type, vessel type, vessel state, time available for evacuation (where applicable and available), geographic region, and number of passengers, among others. This information will not only feed into the overall evaluation, but will also guide model constructs in subsequent elements (e.g., accident type and vessel state will significantly affect the evacuation conditions for the passengers, and thus the time they take evacuating and their decisions along the way).

1.1.4. Select Example Application

While the above analyses will investigate various vessel types, the vessel specific nature of evacuation requires that the actual egress analysis be restricted to one vessel. This selection will be made based upon the data available for populating and validating the model, availability of ship plans, and other criteria. With the framework developed for the vessel type selected, future work can focus on modifications for other passenger vessel types. It is believed that such future modifications would not require extensive or significant work, as much of the methodology and model would be the same for all passenger vessel types. Alternately, various Administrations could work in parallel on the various passenger vessel types, to shorten the development process.

1.2. The Planned Treatment of the Second Element

The second element, as noted, is to model the time and flow of passengers from the time evacuation is needed through to the mustering of the passengers (in personal lifesaving equipment) for immediate embarkation into survival craft or other means of transportation to safety. This will be done in two primary stages; static (where fire and smoke spread, and vessel list and motions are not considered) and dynamic (where they are). As such, the static case is similar to the evacuation of building (with the exception of smoke and fire spread and their subsequent effect on route blocking), and the dynamic case is an extension of this work (and adds motion of the vessel to the full building evacuation methodology).

1.2.1. Develop Queuing Model for Static Analysis

The framework for the egress analysis is a queuing network, which covers the stages shown in Figure 2. This network will be developed to provide for individual evaluations of vessel characteristics, characteristics of the accident driving the need for evacuation, passenger decision making (e.g., does the passenger make the right decision), and passenger capabilities (e.g., speed of movement). These evaluations will be made separately at first, and then overlaid, most likely assuming independence between the passenger decision making and evacuation capabilities. This assumption of independence is perceived (at least initially) to be required due to the sparseness of available data for detailed evacuation analysis. This portion of the analysis will not evaluate the effect of ship motions and other factors; the vessel in this section is assumed to be very similar to a static, upright building.

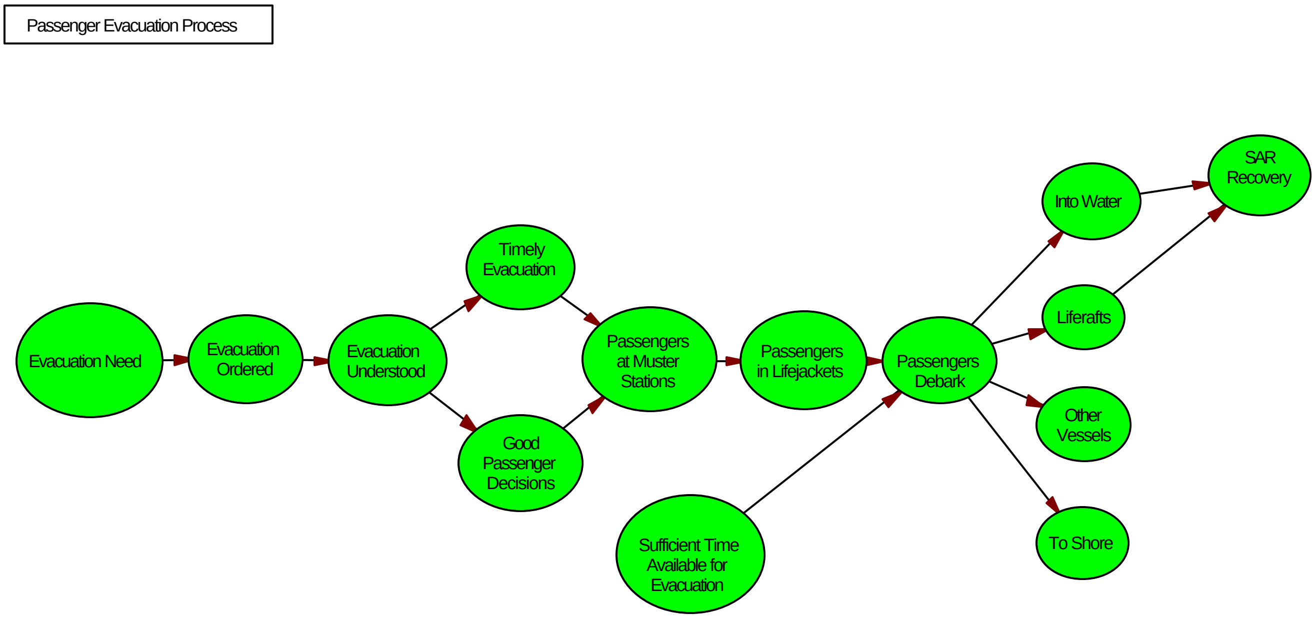


Figure 2

1.2.2. Evaluate Data Sources for Static Queuing Model

For this model, due to the limited amount of maritime specific data in this area, the data available from fire protection analyses for buildings and various transportation modes will be evaluated and applied as applicable for a start. This will include an evaluation of the differences between passenger population and evacuation test pools used for data collection from building evacuation exercises.

1.2.3. Evaluate Static Egress Capabilities for Example Application

Using the model and data from previous steps, the egress capabilities of the vessel chosen for the trial application will be evaluated. Standard queuing measures of effectiveness will be used, including average time for full passenger evacuation. As noted previously, this evaluation will be done individually for passenger decision making and passenger egress capabilities and then a joint evaluation made using both factors with the assumption of independence between the two. If feasible, bounds on the measures of effectiveness will be determined by this (independent) case and by the case assuming full dependence. Again, this will treat the vessel as a fixed structure, with no spread of damage.

1.2.4. Interpret Results of Evaluation versus SOLAS Standard

The results of the previous sections (i.e., the distribution of time required for passenger evacuation, etc.) will be compared to the existing SOLAS method, and conclusions drawn.

1.2.5. Develop Queuing Model for Dynamic Analysis

This section will be performed in a similar manner to, and in fact using the results of, the static model case. The model will be structured to allow the evaluation of the effects of the vessel in motion or not being upright. These effects will likely be modeled as affecting the base transit rates and base decision making error rates in a semi-uniform manner, given the lack of experience and data for more sophisticated models.

1.2.6. Evaluate Data Sources for Dynamic Queuing Model

While certain dynamic effects such as smoke and other performance shaping factors are accounted for in some of the fire protection data sets, factors such as vessel list and movement are not. As such, available maritime (including armed forces) statistics will likely be evaluated as the primary data source. Here, too, international collaboration on data collection would provide for an enhanced ability for the Correspondence Group to be able to adequately consider all factors influencing passenger safety in the evacuation process.

1.2.7. Evaluate Dynamic Egress Capabilities for Example Application

The evaluation of the egress capabilities for the example application under dynamic conditions will be made in an identical fashion as for the static case, with the same measures of effectiveness determined.

1.2.8. Interpret Results of Evaluation

Again, the results of the egress evaluation (dynamic case for this section) will be compared to the existing SOLAS standard and to the static case, and conclusions drawn.

1.2.9. Validate Models

Given the almost complete lack of work in this area, and the sparse nature of detailed data for maritime passenger vessel evacuations, full validation will be impossible. However, at least partial validation will be possible using the results of the trial evacuations attempted in recent years and selected accident case histories. In addition, the United States will continue to pursue more detailed evacuation drills to test various aspects of the methodology and model. International coordination of ongoing drills and exercises provide another opportunity for validating this work and the work of the Correspondence Group, and should be a top priority.

1.3. The Planned Treatment of the Third Element

The third and final element provides a review of the risk and various risk management measures for ensuring passenger safety after departing the vessel.

1.3.1. Develop Methodology for Post-Evacuation Analysis

In order to provide a more complete assessment methodology, it is initially proposed to develop a methodology and model to provide for the evaluation of SAR capabilities. This will allow for not only the evaluation of current SAR asset levels and distribution, but also allow for the consideration of various lifesaving support requirements. This will provide the ability to ensure that adequate infrastructure exists to protect, locate and rescue all passengers- a growing concern given today's rapidly expanding passenger capacity. The United States concurs with the view expressed by various administrations that the ability to address all aspects of the evacuation, from the initial need to evacuate through to passengers safely on shore, is of critical importance to the effectiveness of the Correspondence Group's efforts.

2. Summary

The evacuation model to be developed under the above outline uses a queueing network approach to develop the characterization of the time needed for evacuation. Included in the model are time aspects (for recognition of the need to evacuate, sounding of the alarm, time needed for evacuation, etc.) and passenger decision-making. Three types of factors are used to capture the situational aspects influencing the evacuation; passenger, vessel and accident specific. These macro-level factors are being decomposed into a variety of subfactors, illustrative examples of which are provided in Table 1. The influences of these individual subfactors on the speed and decision-making aspects previously described are currently being investigated in Section 1.2 of the above, in order to fill out and populate the model. As described in Section 1.2, this effort is utilizing the research done for the fire protection, aviation and other transportation communities as an initial baseline, in order to make up for the current gaps in the maritime realm.

Table 1

Vessel		**Passenger**		**Accident**
Compartmentation		Age		Type
Route		Disability		Severity
Crew Experience		Impairment		Sea State
Number of Decks		Fatigue		Precipitation
: :		: :		: :

Specifically, the above process is envisioned as providing a means for both developing and enforcing international policies on evacuation analysis. For developing policy, the approach could be used to evaluate the adequacy of existing regulations and to weigh tradeoffs between various potential requirements. For enforcing policy, the methodology provides a means of ensuring that vessel designs meet established criteria for evacuation times. Specifically, to utilize such a framework in assessing fire and life safety, the following approach is envisioned. First, the layout of the vessel's compartmentation, as well as bulkhead and deck materials and furnishings (with a database of properties such as flame spread, size, etc.) could be imported. This information could then be fed into models for fire, smoke and toxic gas development. Additionally, this information could be used to characterize the evacuation environment (obstacles for the evacuation path, passenger densities, length of evacuation route, etc.). The focus of the current research project is to develop a model of the evacuation environment and process, to provide the probabilistic characterization needed for IMO decision-making and for a full reliability model (including the smoke and damage assessments cited previously).

The results of these efforts will provide the ability to refine the “simplified methodology” by testing the significance of the shipboard environmental factors left out and the assumptions made in the existing guidelines. Additionally, this will provide for a better understanding of the effects of the differences between vessel types, thereby supporting the task before the Correspondence Group to extend the application of the guidelines to not only Ro-Ro passenger ships, but also High Speed Crafts and cruise ships. Furthermore, knowing the influence of these factors, designers will be able to modify evacuation plans to achieve optimal performance.

As noted above, the Correspondence Group (and the team from the United States) is looking to build off of previously completed research and regulations for not only the maritime industry, but also the extensive work done for other transportation modes and for buildings. In order to capture this previously completed work, and as part of the United States’ support of the above, we have established a reference database that at present has over 300 articles, reports and other references. An example of one of the reports is provided in Annex 1. As part of our contribution to the Correspondence Group, we would like to offer to host an Internet page (including this reference database). We believe that this would facilitate a free and open exchange of information that is so critical to such an effort. This database can be reached at http://www.uscg.mil/hq/g-m/nmc/evacuation. Comments or suggestions on the database design and potential modifications would be gratefully appreciated.

Annex 1: Bibliographic Database Sample Report